Discrimination of Low Levels of Green Vegetation Cover Using a High Spectral Resolution Vegetation Index

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1. Introduction

Vegetation vigor or cover status is currently monitored globally using broad-band vegetation indices (e.g. NDVI, PVI, RVI, and SAVI etc). These red versus near-infrared (NIR) vegetation indices operate by contrasting the chlorophyll pigment absorption in the red with the high reflectance of green leaves in the NIR. Under conditions of low (≤30%) green canopy cover, background rock, soil, and litter materials produce a range of vegetation index values, dramatically degrading the accuracy of broad band vegetation indices. Broad-band data are unable to distinguish slope variations from the red to NIR in background materials from the red versus NIR signal of green leaves at green vegetation cover levels of typical arid and semi-arid regions. Our previous field experiment, conducted by high spectral-resolution ASD's PS-2 reflectance data with bandwidth of 4 nm, showed that the narrow-band conventional vegetation indices (DVI, NDVI, PVI, RVI, SAVI, $SAVI_2$, and TSAVI) have higher accuracy than the corresponding simulated broad-band vegetation indices on quantifying vegetation cover, especially the low (≤30% green cover) and very low (≤10% green cover) green cover conditions. However, derivative-based green vegetation indices (DGVI) derived from continuous PS-2 reflectance spectra proved to be the best among all of the tested broad- and narrow-band vegetation indices. DGVI was up to several times better than broad-band NDVI and RVI in prediction accuracy. The highest prediction accuracy of low green cover levels by DGVI is due to DGVI's optimally minimizing background impacts (brightness and red-NIR slope effects) on green vegetation signals centered at the chlorophyll red-edge. DGVI is defined as the integration of 1st/2nd order derivative spectra across chlorophyll red-edge spectral range in reference to a local or zero baseline and focuses on measuring the amplitude of the chlorophyll red-edge. Our previous study with AVIRIS data also revealed that the chlorophyll red-edge feature of Monterey pines can be readily detected in the high spectral resolution AVIRIS reflectance spectra for green cover levels ≥4.8%. Therefore, introduction of DGVI to AVIRIS data could lead to mapping low cover levels

of green vegetation with higher accuracy at larger scale.

2. Methods

Radiometrically calibrated AVIRIS data, which were acquired on October 3 of 1990 over a commercially operated Monterey pine plantation in Jasper Ridge, California, were used for this study. The Monterey pine plantation had nearly identical background soil and single Monterey pine species (*Pinus radiata*). Due to periodic cultivation, understory weeds were basically removed. Field check found only a little dry grass present in the plantation. Low altitude aerial photography of the plantation was acquired before the AVIRIS flight and used in assisting determination of locations and percent green cover levels of 22 sampling sites (Figure 1).

Entire AVIRIS scene of the study area was converted to 1st and 2nd order DGVI values on the pixel by pixel basis. Raw DN spectrum of each AVIRIS pixel was calibrated to ground reflectance in the full AVIRIS spectral range using a series of calibration targets ranging from dark to bright in brightness. The reflectance spectrum of each pixel was subsequently smoothed by a low pass filter to remove high frequency noise. Using equations (1) and (2), the 1st and 2nd order derivative reflectance spectra were then generated separately. Finally, the 1st order DGVI with local baseline correction (1DL_DGVI) and 2nd order DGVI using zero baseline (2DZ_DGVI) values of the pine plantation were calculated using equations (3) and (4). No local baseline correction is necessary for calculating 2DZ_DGVI.

$$\rho'(\lambda_j) = \frac{\rho(\lambda_{j+1}) - \rho(\lambda_{j-1})}{\lambda_{j+1} - \lambda_{j-1}} \qquad (1)$$

$$\rho''(\lambda_j) = \frac{\rho'(\lambda_{j+1}) - \rho'(\lambda_{j-1})}{\lambda_{j+1} - \lambda_{j-1}} \qquad (2)$$

$$1DL\_DGVI = \sum_{\lambda_1}^{\lambda_n} |\rho'(\lambda_j) - \rho'(\lambda_1)| \Delta\lambda_j \qquad (3)$$

$$2DZ\_DGVI = \sum_{\lambda_1}^{\lambda_n} |\rho''(\lambda_j)| \Delta\lambda_j \qquad (4)$$

In equations (1) to (4), i represents band number and λ_i represents center wavelength at the ith band. λ_1= 626.1 nm (band 24) and λ_n=795.8 nm (band 45). The ρ, ρ', and ρ'' represent reflectance, 1st and 2nd order derivative reflectance, respectively.

3. Results

Vegetation signals centered at chlorophyll red-edge were enhanced in both 1st and 2nd

order derivative reflectance spectra. The red-edge feature for the site with 2% green cover level was more recognizable in its derivative reflectance than in the reflectance spectra. Higher linear regression coefficients (r^2 values) were acquired for percent green cover levels of the 22 sampling sites with corresponding 1DL_DGVI and 2DZ_DGVI values (Figure 2).

Both 1DL_DGVI and 2DZ_DGVI maps quantitatively delineated spatial variations of green cover conditions of the plantation and adjacent areas. Based on the existing strong linear relationship between the DGVI values and green cover densities of 22 sample sites from the pine plantation, the percent green cover levels of entire Monterey pine plantation were inversely estimated, including the areas with ≤1% cover level. The two percent green cover maps generated from 1DL_DGVI and 2DZ_DGVI showed very similar green distribution patterns. Visual examination of these two percent green cover maps showed that all of the 22 sample sites fall in the correct range of green cover (Figure 3).

4. Conclusion

Monitoring of green vegetation in arid and semi-arid lands will be substantially improved using imaging spectrometer data (e.g. AVIRIS data) with a continuous series of narrow bands across the chlorophyll red-edge region. Detection limit of low green cover levels can be further enhanced in derivative reflectance spectra of AVIRIS data. DGVI, which is developed on the basis of minimizing the linearly mixed background impacts on green vegetation signals, is a very effective and practical way to observe variations in green vegetation cover in arid and semi-arid regions.

5. Acknowledgements

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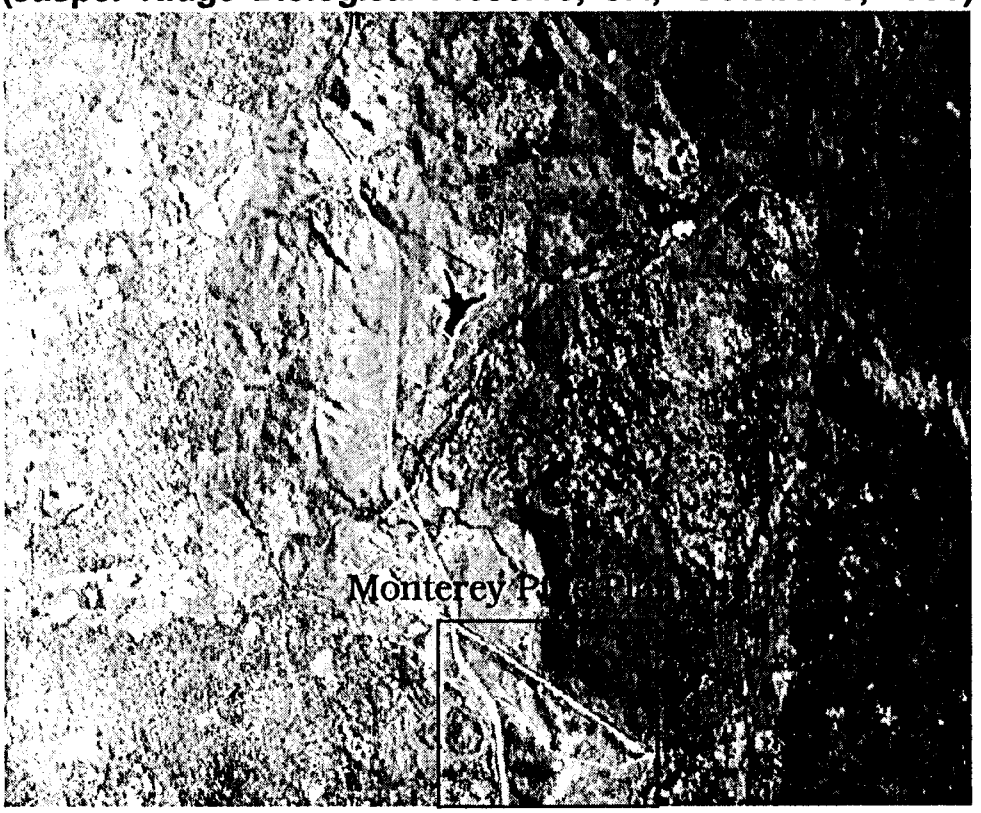
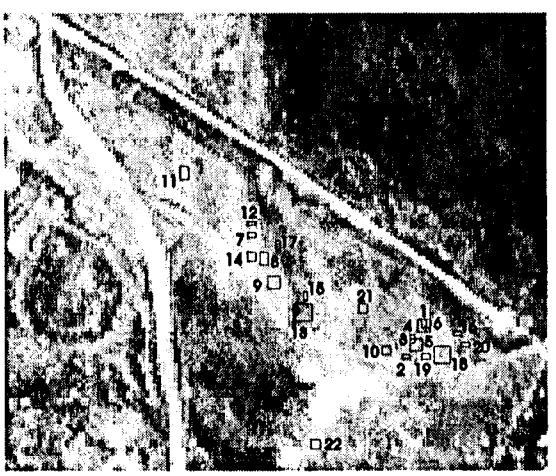
Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)
(Jasper Ridge Biological Preserve, CA; October 3, 1990)





Red: 805.4 nm (CH. 46)
Green: 557.4 nm (CH. 17)
Blue: 449.5 nm (CH. 6)

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Figure 1. AVIRIS 3-band false color composite of Jasper Ridge Biological Preserve, CA. The bottom image contains the Monterey pine plantation with 21 sample stands inside. The no. 22 stand is outside the plantation.

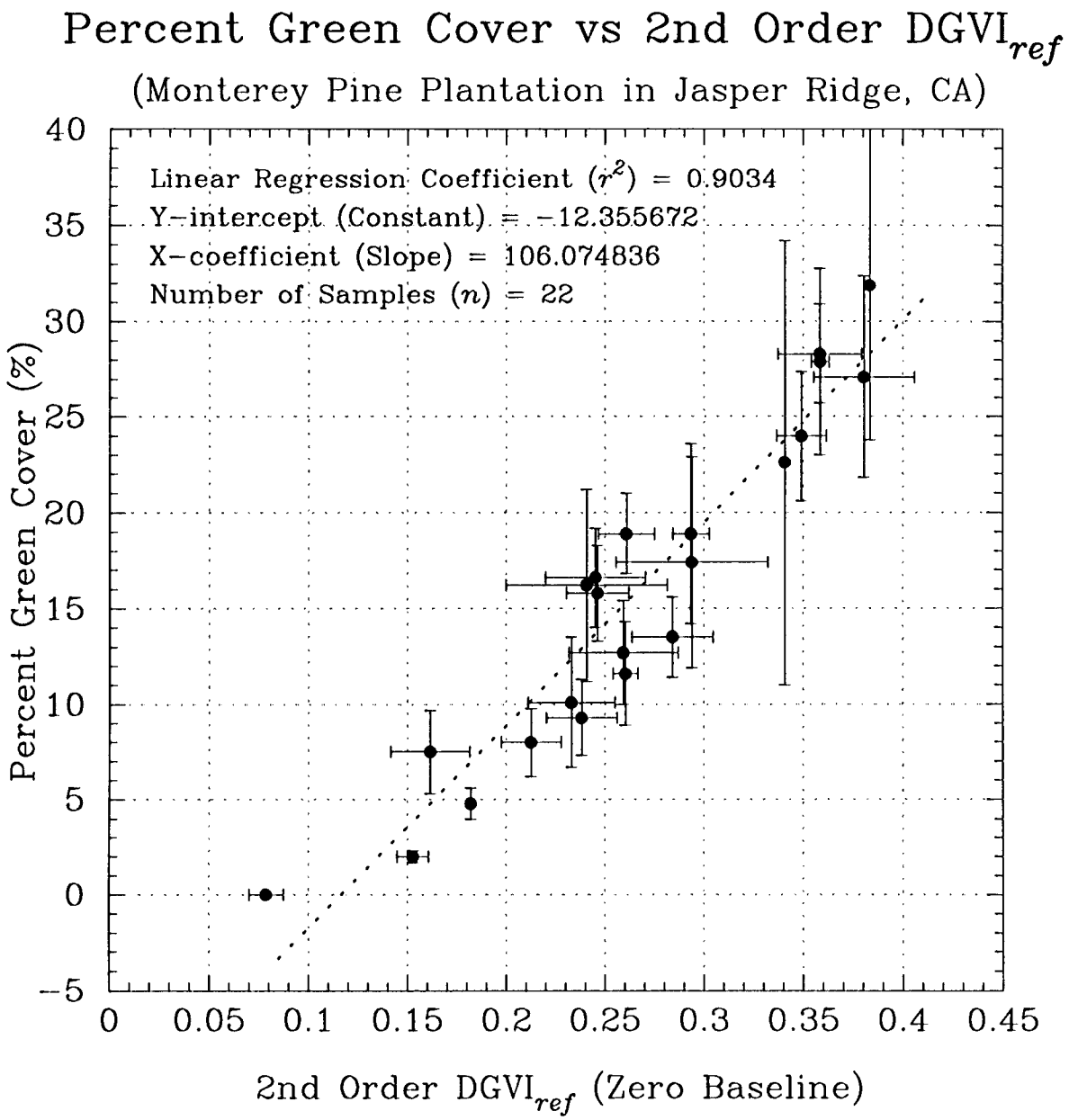
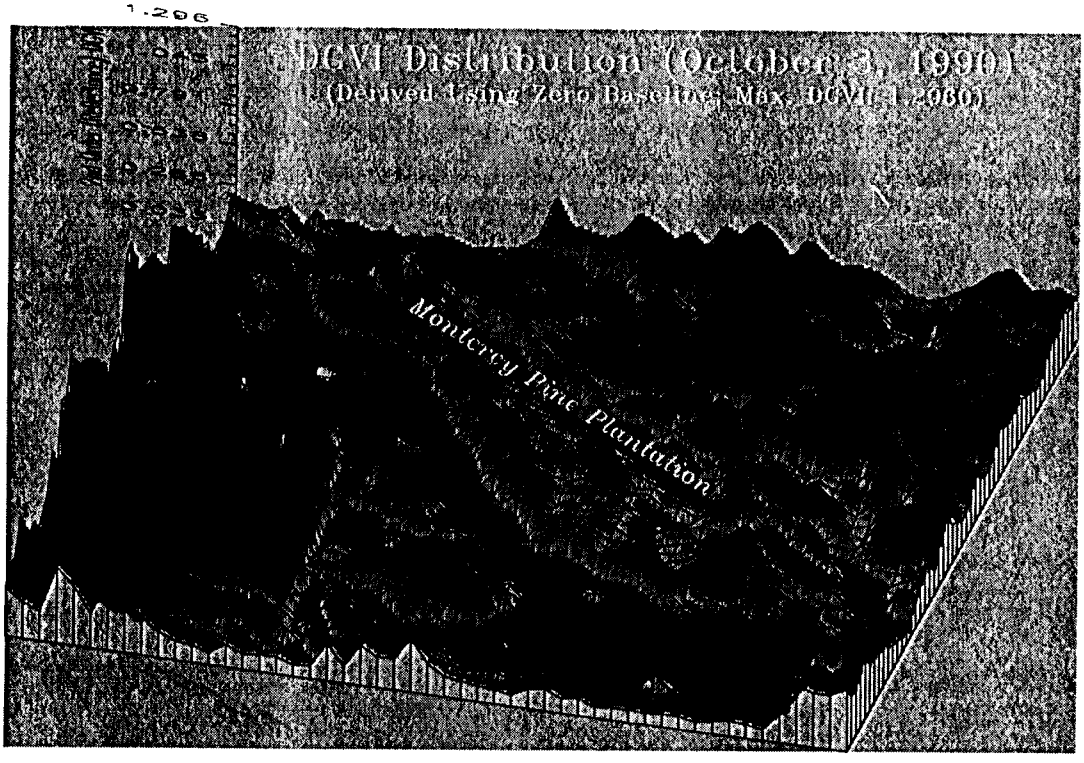
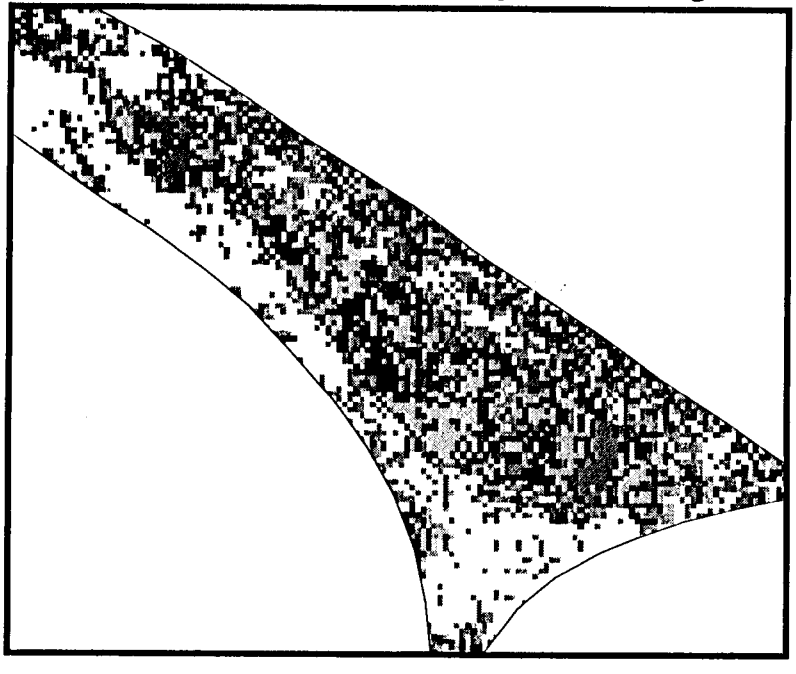


Figure 2. Percent green cover levels of 22 sampling sites versus 2nd order DGVI calculated from AVIRIS reflectance in reference to zero baseline (2DZ_DGVI). Horizontal and vertical bars represent standard deviations of the 2DZ_DGVI and percent green cover data.



2nd Order DGVI Distribution
(Derived From Reflectance Spectra Using Zero Baseline)



Green Cover Level (%)

White:	< 1
Cyan:	1 - 4
Blue:	4 - 7
Green:	7 - 10
Light Green:	10 - 15
Red:	15 - 20
Orange:	20 - 30
Yellow:	> 30

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Figure 3. Top: 2DZ_DGVI (2nd order derivative-based green vegetation index derived using zero baseline) distribution pattern of Monterey pine plantation and adjacent areas in Jasper Ridge, CA; Bottom: Percent green cover of Monterey pine plantation estimated from the 2DZ_DGVI values.